Report on Ocean Dumping R and D Pacific Region Department of Fisheries and Oceans 1982-1983

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DEPARTMENT OF FISHERIES AND OCEANS

1982-1983

Edited by

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RESUME

Woods, S.M. (ed.). 1984. Report on Ocean Dumping R and D Pacific Region. Department of Fisheries and Oceans 1982-83. Can. Contract. Rep. Hydrogr. Ocean Sci.:17.38p.

La recherche sur les rejets en mer au cours de l'année 1982-1983 a fait l'objet d'un examen durant un atelier tenu a l'Institut des Sciences de la Mer. Les minutes ont été recueillies pour fins de publication. Les études commanditées par C.C.R.I.R.M. presentées au cours de cet atelier ont inclus les taux de décharge de métaux à la mer provenant de sédiments contaminés et l'accumulation en tissus de contaminants reliés aux sédiments, ainsi qu'une analyse des sédiments maritimes surficiels de la mer Beaufort. Au cours d'une étude, en eau marine propre, de l'adsorption et du rejet de cadmium et plomb, provenant de sédiments à la fois riches en matières organiques et grossement contaminés, on a observé deux modèles de comportement distincts et réplicables. Une étude pour développer un protocole d'assayage pour prédire l'accumulation en tissus causée par les dépouilles de dragues contaminées a indiqué une accumulation en tissus marquée de cadmium, plomb et PCB provenant des échantillons d'essai. Il est suggéré que le protocole pourrait servir comme "avertissement" envers l'accumulation potentielle en tissus de ces détritus solides destinés pour décharge en mer. Aucune accumulation évidente ou changements significatifs dans les paramètres de sang de poisson ont été apparants dans une étude semblable, mais de courte durée, gérée sur les soles et les vers polychètes. La recherche sur les échantillons de sédiments et le biota benthique amassés en 1982 et 1983 le long de la péninsule Tuktoyaktuk est toujours en progrès, ainsi qu'en est l'interprétation des données. Des études multidisciplinaires dirigées dans Puget Sound ont révélé des correlations positives entre les fréquences de néoplasmes au foie et autres lésions du foie dans les poissons de fond et les concentrations d'hydrocarbones aromatiques et/ou des métaux dans les sédiments; telles correlations n'ont pas été trouvées avec les hydrocarbones chlorinés. Un intérêt continuel envers l'exactitude et la précision de données analytiques soumises avec les demandes pour permits O.D.C.A. a été exprimé au cours de cet atelier. Afin d'assurer la stipulation de données acceptables, C.C.R.I.R.M. (Pacific) exécutera un protocole assurant la qualité à compter de 1984.

Mots-clés: Rejets en mer, Effets environmentals

ABSTRACT

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A review of ocean dumping research for 1982-1983 was carried out at a workshop held at the Institute of Ocean Sciences and the proceedings have been assembled for publication. R.O.D.A.C.-funded studies presented at the workshop include release rates of metals to seawater from contaminated sediments and bioaccumulation of sediment-associated contaminants, as well as analysis of Beaufort Sea surficial marine sediments. In a study of the adsorption and release of cadmium and lead from organic rich, heavily contaminated sediments into clean seawater, two distinct, reproducible behaviour patterns were observed. A study to develop a bioassay protocol for predicting bioaccumulation from contaminated dredge spoils indicated significant bioaccumulation of cadmium, lead and PCB's from some of the test sediments. The protocol was recommended as a test to "red flag" the bioaccumulation potential of solid wastes destined for ocean disposal. No obvious bioaccumulation or significant changes to fish blood parameters were apparent in a similar, but shorter-term, study conducted on flatfish and polychaete worms. Work is still progressing on the analyses of sediment samples and benthic biota collected in 1982 and 1983 along the Tuktoyaktuk Peninsula and on the interpretation of the data. Multidisciplinary studies conducted in Puget Sound have revealed positive correlations between the frequencies of liver neoplasms and other liver lesions in bottomfish and concentrations of aromatic hydrocarbons and/or metals in sediments; such correlations were not found with chlorinated hydrocarbons. Continued concern regarding the accuracy and precision of analytical data submitted with applications for O.D.C.A. permits was expressed at the workshop. In order to ensure the provision of acceptable data, R.O.D.A.C. (Pacific) will be implementing a quality assurance protocol to commence in 1984.

Key words: Ocean dumping, Environmental effects

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1. SUMMARY AND CONCLUSIONS

R.O.D.A.C.-funded research contracts for 1982-1983 were reviewed at a workshop held on December 2, 1983 at the Institute of Ocean Sciences, Sidney, B.C. The studies included research on release rates of metals to seawater from contaminated sediments and on bioaccumulation of metals and polychlorinated biphenyls, as well as a coastal sediment/benthic invertebrate survey along the Tuktoyaktuk Peninsula in the Beaufort Sea. This report summarizes the information presented by the R.O.D.A.C. contractors and the guest speakers at the workshop, and also contains a brief review of the proposed protocol regarding analyses required for the granting of ocean dumping permits by R.O.D.A.C.

One of the problems related to the disposal of dredge spoils is the lack of reliable information regarding the release of heavy metals, such as cadmium and lead, from the dredged sediments into seawater. In order to address this concern, organic-rich, heavily-contaminated sediments from False Creek, Vancouver, B.C. were mixed with clean seawater in the proportions of 1ppm, 10ppm and 100ppm, and sampled and analysed under ultra-clean laboratory conditions over a five-week period. The adsorption and release of cadmium and lead into clean seawater presented two distinct, reproducible, behaviour patterns. For cadmium, an immediate drop followed by a dramatic release after 48 hours was observed. For lead, a gradual monotonic increase in levels began around 4 hours for the three sediment concentrations. However, different behaviour was noted in the latter stages of the experiment for each level of suspended matter.

In a study to develop a bioassay protocol for predicting bioaccumulation from contaminated dredge spoils, a deposit-feeding clam (Macoma balthica) was exposed in the laboratory for a period of six months to three test sediments containing cadmium, lead and polychlorinated biphenyls and to a reference sediment. Resident biota (clams, polychaete worms, flatfish and crabs) from the same contaminated test sites were sampled in the field for comparison. Both laboratory and field studies indicated significant bioaccumulation of cadmium from the Powell River (pulp and paper mill effluent discharge) site, and bioaccumulation of lead from all test sites, compared to the reference sediment. Significant bioaccumulation of PCB's was evident from both the field and laboratory data. It was suggested that similar laboratory studies could be used to "red flag" the bioaccumulation potential of solid wastes destined for ocean disposal.

A parallel study was conducted to examine the effects of a 75-day exposure of polychaete worms and flatfish to dredged deposits high in heavy metal content (arsenic, cadmium, copper, lead and zinc). Following the first 60 days, when the fish had been separated from the worms by a plastic screen laid over the sediment, the fish were allowed to feed on the worms thus permitting additional uptake of metals by fish from contaminated food. No obvious bioaccumulation of any of the metals

occurred during the experiment and there were no significant changes in any of the fish blood parameters (ALA-D; haematocrits; leucocrits; plasma levels of sodium, potassium and calcium) measured. The overall absence of metal bioaccumulation or metal-induced toxicity or stress may be attributed to insufficient exposure of the fish to the contaminants. It was concluded that, over a short time period, the organic content of dredge sediment from Burrard Inlet may be more toxic to marine life than the metal content and that future experimentation should be directed towards studying the effects of ingestion of polluted food material.

In order to assess any potential effects on the Beaufort Sea environment resulting from increasing industrial activity, it was recognized that a coherent data set of sediment geochemistry and benthic invertebrate biology was required. As a result, a coastal sediment/benthic invertebrate survey, at 110 and 53 stations respectively, was conducted along the Tuktoyaktuk Peninsula during the summer of 1982. Geochemical parameters studied included sediment grain size; wet weight, ash weight, dry weight; total organic carbon; hexane extractable compounds; total metals (chromium, iron, nickel, copper, zinc, cadmium, mercury, lead); and aliphatic and polynuclear aromatic hydrocarbons. Taxonomic identification and enumeration of the benthic biota proceeded to class/order. A data report has been prepared but detailed analyses and interpretation of the data are on-going. A second year of sampling (1983) has been completed and will add to the data base.

Multidisciplinary studies of relationships between pollutants and diseases in bottom-dwelling fish in Puget Sound have revealed high concentrations of a large number of anthropogenic chemicals in sediments. Positive correlations were found between the frequencies of liver neoplasms and other liver lesions in English sole (Parophrys vetulus) and Pacific staghorn sculpin (Leptocottus armatus) and concentrations of total aromatic hydrocarbons and/or metals in sediments; such correlations were not found with chlorinated hydrocarbons. The field and laboratory studies have provided important initial insights into cause-and-effect relationships between chemicals and diseases in fish. It is likely that similar investigations would reveal comparable serious pollution-related health problems in marine life in many other urban areas of the world.

A brief review of Pacific Region ocean dumping data files reveals not only variability in the application of analytical methods but also incomplete reporting of methods and chain of custody/sampling and, frequently, a lack of a statement of accuracy. If comparison is to be attempted and appropriate decisions made as to whether or not a sediment proposed for dumping is in violation of the Ocean Dumping Control Act (O.D.C.A.), it is essential that laboratories determine their precision and accuracy for analyses of environmental samples. Use of recognized control methods helps establish and maintain quality. Feedback from well-designed controls can help the analyst convince himself and others that the data are within the stated bounds. It then becomes possible to compare these data with regulatory limits or with data which have been collected in like manner.

In order to ensure the provision of such comparable data, R.O.D.A.C. (Pacific) will be implementing a quality assurance protocol to commence in 1984. Following the completion of a round-robin laboratory performance check, R.O.D.A.C. will have on file information packages describing the methods and quality-control procedures used by the laboratories which took part in the check. In order to receive approval from R.O.D.A.C., all future applications for ocean dumping permits will need to be accompanied by a certification that the analyses were conducted in accordance with the procedures described in the file or in accordance with updated descriptions which must accompany the application.

Extended abstracts of the studies contracted in 1982-1983 are contained in this report. Inquiries regarding the presented information and further publications should be directed to the listed scientific authorities at their associated institutions. Appendix I lists the abbreviations and addresses of these institutions.

A list of those who attended the workshop is contained in Appendix II. Appendix III outlines contracts for 1982-1983 while studies contracted for 1983-1984 are listed in Appendix IV.

Copies of this Canadian Report of Hydrography and Ocean Sciences are available for distribution from the Institute of Ocean Sciences, Sidney, B.C.

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2. RELEASE OF CADMIUM AND LEAD FROM FALSE CREEK SEDIMENTS: A LABORATORY STUDY

V.J. Stukas

Contractor: Seakem Oceanography
Prepared for: C.S. Wong, I.O.S.

One of the problems related to the disposal of dredge spoils, such as those obtained from False Creek, Vancouver, B.C., is the lack of reliable information regarding the release of heavy metals, such as cadmium (Cd) and lead (Pb), from the dredged sediments into seawater. The absolute low levels of these metals - low part per trillion (ppt) range - in coastal seawater (Stukas and Wong, 1981, 1983) presents major obstacles for laboratories not equipped with clean rooms and accurate sampling systems. While the release of Cd, Pb and Zn (zinc) have been observed in the actual disposal of mine tailing in seawater (Stukas, 1983), and of Pb - but not Cd - in laboratory studies of mine tailing (Hoff et al, 1982), the organic rich sediments from False Creek have a different character and thereby potentially different behaviour. Mine tailing slurries tend to be organically poor and high in iron/manganese (Fe/Mn) oxide surfaces. A recent study of trace-metal adsorption characteristics of estuarine particulate matter indicated widely different binding properties for Cd and Pb onto organic rich sediments or those with high Fe/Mn oxide surfaces (Lion et al, 1982).

In the present study, the leaching of organic-rich, heavily-contaminated sediments in clean seawater was analysed under ultra-clean laboratory conditions. Cd and Pb rich sediments from False Creek were mixed with seawater from Saanich Inlet to attain three concentrations of suspended matter. The seawater was recirculated and sampled over a five week period. Clean, coastal seawater, collected from 30 m in Saanich Inlet, was analysed by isotope dilution mass spectrometry (IDMS) for Cd and Pb and then exposed to varying amounts of Cd-Pb rich sediments from False Creek. Triplicate 20 L carboys of each level of suspended matter - 1 ppm, 10 ppm and 100 ppm - were continuously stirred by a small peristaltic pump under ultra-clean room conditions. Samples were aspirated/filtered into ultra-clean 1 L polyethylene bottles over the period of five weeks. These were extracted with 0.001% dithizone for soluble Cd and Pb. The double spike version of isotope dilution mass spectrometry was employed to supply the high degree of accuracy and precision required for low level comparisons of Cd and Pb analyses (1%, 1-5%, respectively; Stukas and Wong, 1983). Blanks and detection limits are presented in Table 2.1.

The adsorption and release of Cd and Pb from False Creek sediments into clean seawater presents two distinct, reproducible behaviour patterns. For Cd (Figure 2.1), an immediate drop, followed by a dramatic release after 48 hours, was observed. The rapidity of the adsorption, and the extremes in the minima and maxima obtained, were directly proportional to the amount of suspended matter used. Binding of the seawater-derived

Cd appears to be related to the organic sites in the sediment (Lion et al, 1982), whereas the subsequent release of this Cd, plus some innate to the sediment itself, may be related to the oxidation of the Cd or Cd-humic complexes.

The depression in Cd levels and subsequent release can be readily correlated with the sedimentation rate, wherein a rapid suspension and subsequent settling of the particles occurs almost entirely in the first 24 hours. This rapid pulse in sedimentation correlates well with the rapid uptake of Cd from seawater, whereas the "quiescent period" correlates with the release of Cd. The fraction of metal adsorbed and the amount subsequently released varies directly with the level of suspended matter. The former is somewhat analogous to the titration of a metal cation with a dissolved complexing ligand. As the False Creek sediments are organic rich (with 5.6% C, C/N = 22; F. Whitney, pers. comm.), humic ligands are thought to be the prime candidate for complexing the Cd. Investigation of surface binding properties or organics and Fe/Mn oxides (Lion et al, 1982) indicated that a substantial fraction of Cd (ca 50%) was directly associated with the organic phase. A similar release pattern was observed at pH 5.5 (ibid) in their kinetic study of salt marsh sediments. (This present study was conducted under natural pH's of 7.70.)

The release of Cd from the sediments, however, may be related to other factors. By considering the mass balance for Cd at each of the different levels of suspended matter together with the maximum value or plateau in Cd levels, information as to the source of the released Cd may be obtained (Table 2.2). From these considerations, neither the simple release of Cd that had been adsorbed from seawater nor the direct leaching of the Cd in the sediments can solely account for the elevated levels observed. It would appear that the Cd adsorbed from seawater, bound most likely into sites of low energy, should be preferentially released over that innately bound in the (humics) sediment. However, as both sources are required to explain the data, a mechanism is required to liberate a significant fraction of the Cd innate to the sediment. One such mechanism may be related to the slight decrease in dissolved oxygen which began at 48 hours and appeared significant (1 mL/L for all levels of suspended matter) by the two week sampling period. There is insufficient carbon (C) in the 1 ppm suspended material to account for the oxygen decrease by CO_2 production by bacteria. An alternate prospect is the oxidation of Cd or Cd-humic complexes in the False Creek sediments themselves. The oxidized Cd would be much more soluble.

The behaviour of Pb release from False Creek sediments (Figure 2.2) appears much simpler than the above case. Mass-balance considerations indicate the existence of a large reservoir of Pb in the sediment. A gradual, monotonic increase in levels begins around 4 hours. For the two higher levels of suspended matter, the initial release rates are quite similar. However, different behaviour is noted in the latter stages of the experiment for each level of suspended matter. At 1 ppm levels, the Pb release appears to pass through a maximum of about 100 ng/kg and decreases to about 60 ng/kg by the end of five weeks. Since adsorption related to wall effects is small at these concentration

levels (Stukas and Wong, 1983), the most likely sink may be the sediment itself. While Fe/Mn oxide surfaces are of greater importance in binding Pb than organic coatings (Lion et al, 1982), either site may still be a possible sink for a limited amount of Pb. At 10-ppm levels of suspended matter, the release of Pb tends to level off at approximately 200 ng/kg. No definite sign of adsorption, as in the above cases, is seen by the end of five weeks. However, at 100-ppm levels of suspended matter, the general trend in the data indicates a continued release of Pb beyond the five- week study period. The erratic behaviour of the averaged data is believed to be an artefact created in part by averaging limited data with poor yields. Since a substantial increase in carbamates, used for the five week sample, resulted in a slight increase in yields to 4%, some metals (Zn?) other than Cd and Pb must be released in large enough quantities to swamp the available sites in the dithizone. Cautionary advice should be given to workers using yield dependent methods. Such low yields at this sampling time would create an adsorption artefact, the opposite of what actually appears to occur.

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TABLE 2.1 Blanks, detection limits and quantitation limits

	Cd (ng/kg)	Pb (ng/kg)
Average Blank	0.095	0.180
Error in Blank ($1S_B$)	0.013	0.010
Detection Limits ($3S_B$)	0.02	0.03
Instrumental (MS) Detection Limits (in ng)	0.000002	0.000003
Quantitation Limits ($10S_B$)	0.13	0.10
Smallest Observed Values in Study	0.97	5.5
Replication (based on 250 g of SW)	63.2 ± 1.5 63.4 ± 1.9	39.9 ± 1.0 41.5 ± 1.2

NOTE: Air exposure rate in IOS ultra clean room is 0.0001 ng Cd/d and 0.002 ng Pd/d.

Table 2.2 Cadmium (Cd) mass balance

Carboy	Cd available in sediment (ng)	Cd adsorbed from seawater (ng)	Cd in seawater at 48 hr (ng)	Seawater remaining after 48 hr (kg)	Cd concentration in seawater (ng/kg)			Maximum observed
					Theoretical			
					a	b	c	
C1 to C3 (1 ppm)	63 ± 8	176 ± 50	1078 ± 37	14.3	88 ± 3 (51%)	80 ± 6 (<100%)	92 ± 7	81.6 ± 1.6
C4 to C6 (10 ppm)	630 ± 80	1206 ± 30	608 ± 20	14.1	129 ± 4 (95%)	88 ± 7 (>100%)	173 ± 10	124 ± 2
C7 to C9 (100 ppm)	6300 ± 800	1602 ± 34	272 ± 18	14.1	133 ± 4 (>100%)	470 ± 60 (>100%)	580 ± 60	538 ± 8

a. all Cd adsorbed by the sediment from seawater released at ca 100 hr
b. only Cd innate to the sediment released at ca 100 hr
c. Cd from both sources released at ca 100 hr

Values in brackets indicate proportion of Cd released to attain the maximum observed value. Cd concentration in the sediment estimated at 3.0 ± 0.3 ppm

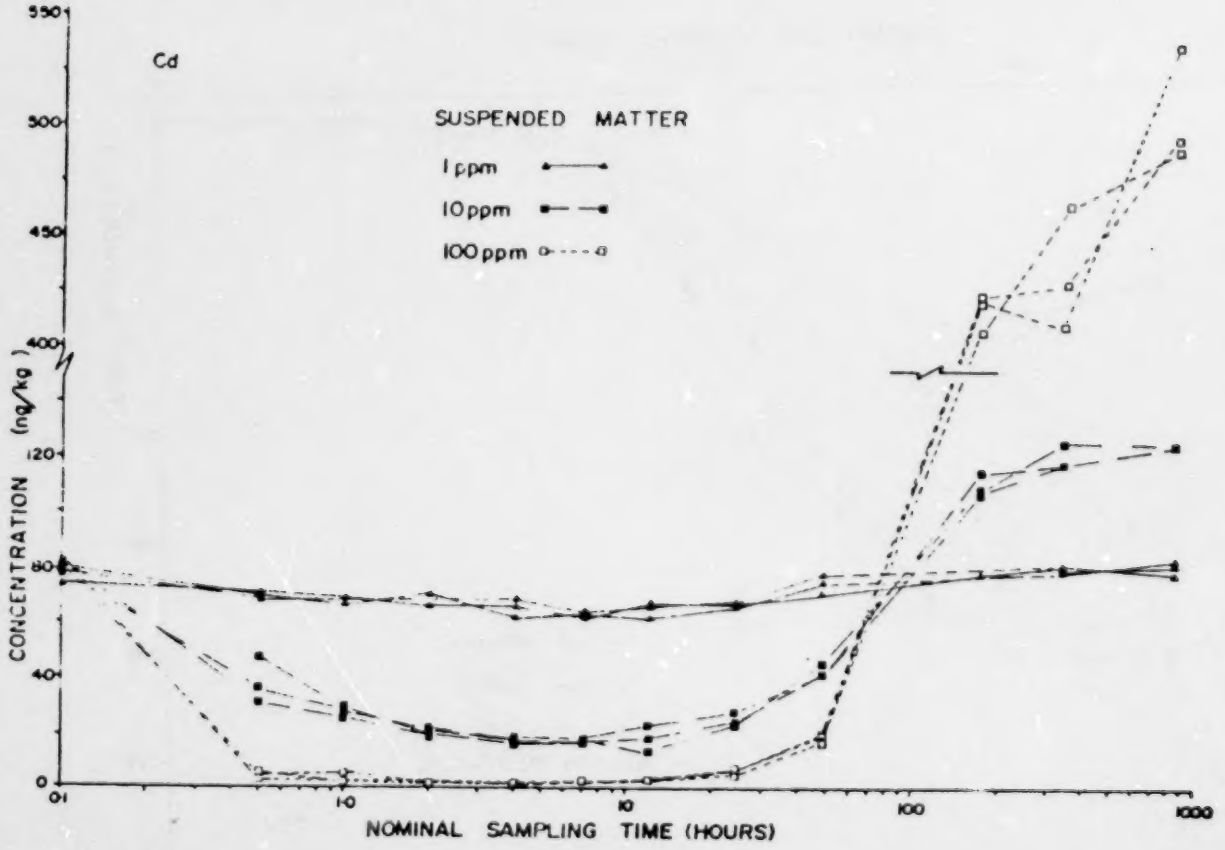

FIGURE 2.1 Adsorption and release of cadmium in seawater by False Creek sediments. (Note the break in the scale changes and the consistency of the triplicates.)

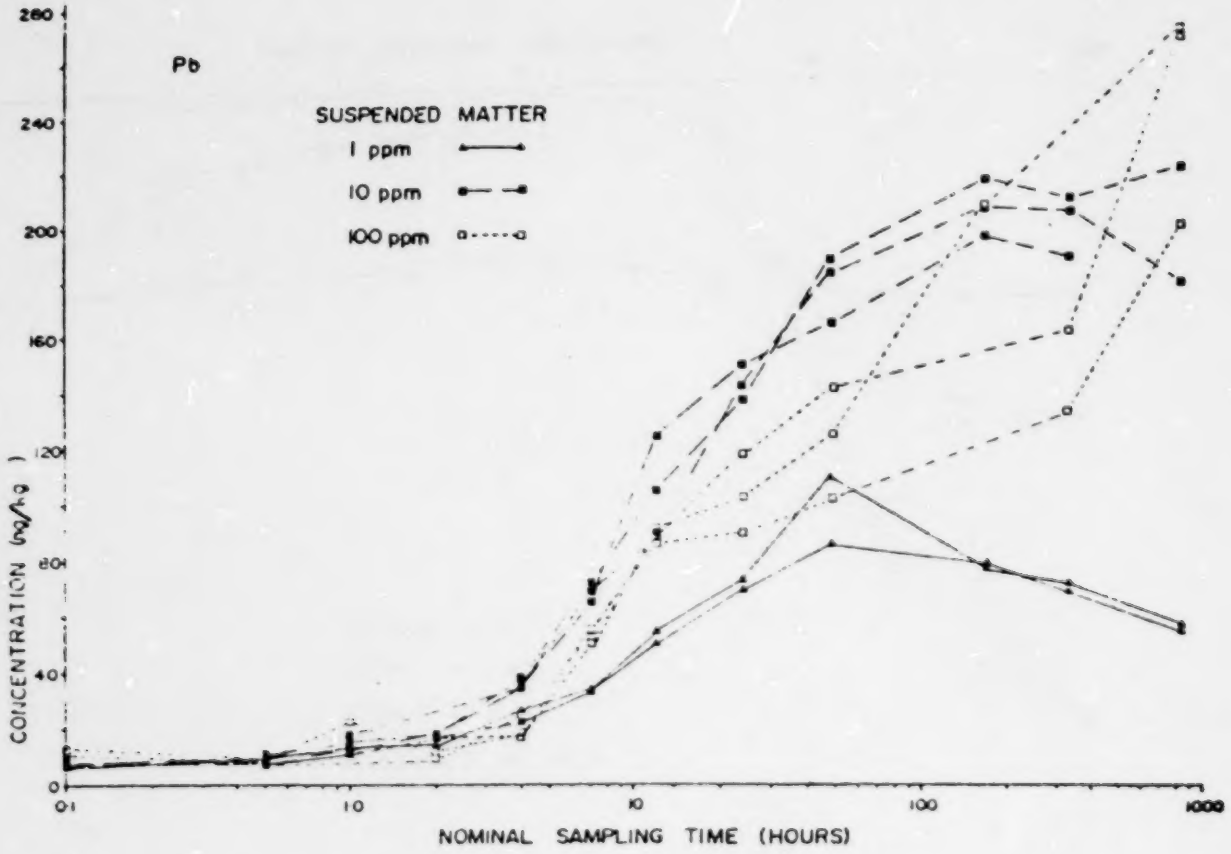

FIGURE 2.2 Release of lead in seawater by False Creek sediments. (Data for 100 ppm at 1 week and at 2 weeks are poor on account of very low yields.)

3. DEVELOPMENT AND EVALUATION OF BIOASSAY PROTOCOL FOR PREDICTING THE BIOACCUMULATION POTENTIAL OF SEDIMENT-ASSOCIATED CONTAMINANTS

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Subcontractor: A.S.L. Ltd.[2]
Prepared for: H. Nelson, E.P.S.

This study represented an initial step towards the development of a bioassay protocol for predicting bioaccumulation from contaminated dredge spoils. The study consisted of two distinct phases: 1) a six month laboratory exposure of a deposit-feeding clam (Macoma balthica) to contaminated test sediments, and 2) a field sampling programme to assess bioaccumulation in resident biota from the same contaminated sites tested in the laboratory. M. balthica was chosen as the test species because it had been shown previously to be a good indicator of the bioavailability of a number of sediment-associated contaminants. This species was considered to have the potential to be used in predicting the relative degree of bioavailability of contaminants to other bottom-associated species. Resident biota sampled for comparison included clams, polychaete worms, flatfish (muscle and liver) and crabs. Three contaminated test sediments representing a drydock/ship repair facility (Vancouver Harbour), a heavily industrialized embayment (False Creek), and a pulp and paper mill effluent discharge (Powell River) were used in the tests. A fourth sediment from a site with no known sources of contamination served as a reference. Contaminants tested included cadmium, lead and polychlorinated biphenyls (PCB's).

A statistically significant difference ($p < 0.05$) in the bioaccumulation of cadmium was observed at one and four months in the laboratory for Powell River sediment. M. balthica did not show any significant uptake of cadmium from any of the other test sediments compared to the reference, despite the high levels of cadmium present (eg. 2.78 ug/dry g in False Creek sediments). Results of the field studies showed levels of cadmium in polychaete worms and flatfish liver to be significantly higher at the Powell River site compared to the reference site. Thus, results which would have been predicted from the laboratory (ie. the high degree of bioavailability for cadmium at the Powell River site) were corroborated by the field sampling.

Lead was bioaccumulated significantly ($p < 0.05$) by M. balthica from all test sediments compared to the reference sediment. In the field, polychaete worms from all test sites, and crab muscle from Vancouver Harbour had significantly higher concentrations of lead compared to the reference site. Fish livers from Vancouver Harbour showed the highest level of lead (3.41 ug/dry g) when compared to the reference site (1.77 ug/dry g). This difference was not statistically significant due

to the high degree of variability and low number of replicate samples (n=2). However, there was general agreement between the laboratory and field results with respect to lead.

PCB's were measured in the reference and Vancouver Harbour sediments only. Both Aroclor 1254 and 1260 were bioaccumulated significantly ($p < 0.05$) from the Vancouver Harbour sediment compared to the reference sediment in the laboratory. Analysis of resident biota also showed significantly higher levels of PCB's in polychaete worms and in flatfish livers from the Vancouver Harbour site.

One problem encountered in the long-term laboratory bioassays was the chronic toxicity of some of the test sediments. Mortalities in sediments from False Creek reached 40% after four months' exposure. This reduced the amount of tissue for analysis, particularly for the six month sampling period.

Our results showed that laboratory sediment bioassays using M. balthica could be used to predict significantly higher levels of bioaccumulation in resident biota from the same contaminated test sites. Positive results from similar laboratory studies could be used to "red flag" solid wastes destined for ocean disposal with respect to bioaccumulation.

Further testing to refine the protocol is required. Aspects identified during the present study which require additional development work include: problems with sediment toxicity, standardization of flow rates and exposure time in laboratory bioassays, significance of various levels of bioaccumulation to resident species, application of the bioassay protocol to a wider number of contaminants, and the use of alternate methods of chemical analysis of sediments to predict bioaccumulation.

4. A STUDY TO ASSESS THE POSSIBLE BIOACCUMULATION AND SUBLETHAL TOXICITY OF ARSENIC, CADMIUM, COPPER, LEAD AND ZINC FROM OCEAN-DUMPED MATERIAL, BY POLYCHAETE WORMS AND BENTHIC FLATFISH.

G.P. Haywood, M.B. Yunker and T.A. Smyth

Contractor: Dobrocky SEATECH Limited
Prepared for: J.A.J. Thompson, I.O.S.

This study was designed to examine the effects over a 75-day period of exposure of polychaete worms and juvenile flatfish to dredged deposits high in heavy metal content and considered unsuitable for ocean dumping. Both groups of organisms were exposed to 'Control' (low metals content) and 'Polluted' (high metals content) sediments from Burrard Inlet (Table 4.1). The 'Polluted' sediments were made up from initial dredged sediments which were found to be so high in organic content that animals could not be successfully maintained in them for more than two weeks. These initial sediments were designated 'Full-Polluted' sediments and were mixed with clean sediments in a ratio of 1:2 (respectively) to form the 'Polluted' sediments used throughout the rest of the testing.

For the first 60 days, worms and fish were exposed to similar sediments and water in the same tanks, but were kept separate by means of 2 mm mesh plastic screens which covered the sediment surface at the bottom of each tank. Sampling of both worms and flatfish was carried out after 15, 30 and 60 days. At the 60-day sampling date, the plastic screens were removed and fish were allowed to feed on the remaining worms, thus allowing for additional uptake of metals by fish from contaminated food. The remaining fish were then sampled after a further 15 days (75 days total).

Sediments and tissues of worms and flatfish were analysed for levels of arsenic, cadmium, copper, lead and zinc. Fish blood was assayed for delta-aminolevulinic acid dehydratase (ALA-D) activity and for plasma levels of sodium, potassium and calcium; haematocrits and leucocrits were also measured. All fish blood parameters were examined as possible indicators of sublethal toxicity and associated stress.

Fish held in laboratory maintenance tanks prior to experimentation showed negligible difference in the health parameters measured (ALA-D, haematocrits, leucocrits, blood cations) as compared with Wildstock fish freshly caught from the field. They were therefore considered to exhibit normal health.

During the experiment no obvious bioaccumulation of any of the five metal species was apparent, although tissue zinc levels appeared fairly substantial in all fish and worms, suggesting that bioaccumulation of zinc had already occurred in organisms, even from the 'Control' sites. In fact, over the course of the experiment, there appeared to be a slight loss of zinc from the fish.

Although not statistically significant, blood parameters showed a slight drop in ALA-D activity for fish exposed in Polluted tanks over the first 15 days. Little difference between these fish and Control fish was observed over the remaining period. Negligible effects of pollution on blood plasma cations were observed, but this could be explained by the low levels of cadmium present in the water as compared with levels used by Larsson et al (1981), whose study indicated markedly disturbed ionic balance after a two-week exposure to cadmium levels of 0.1-10 mg Cd/L.

The overall absence of metal bioaccumulation or metal-induced toxicity or stress may be attributed to two possible causes. First, water flow through all experimental tanks may have been too great, causing leached metals to wash away thereby shortening the effective duration of metal contamination. Second, the organic content of the original Polluted sediment was so high that worms could not survive in it, and it had to be 'cut' with clean sediment. Consequently, this reduced the metal content to a point which may have been too low to produce effects over the time period measured. Insufficient exposure of fish, either in terms of concentrations or time, appears to have prevented any observable effects of the metals.

In conclusion, over a short time period of one to two months, the organic content of Burrard Inlet dredge sediment appears to have been more toxic to marine life than was the metal content. However, longer-term studies are needed to examine further the effects of metals. Previous work has suggested that uptake of metals directly from either seawater or sediments by marine organisms is not the major source of metal contamination. It seems that ingestion of metal-contaminated food is by far the major cause of raised metal body burdens in many organisms. With this in view, it is felt that future experimentation should be directed towards studying the effects of ingestion of polluted food material, such as invertebrates collected from ocean-dumping sites. Several methods and experimental modifications which would better resolve this problem have become apparent as a result of this study.

REFERENCES

Larsson, A., B-E Bengtsson and C. Haux. 1981. Disturbed ion balance in flounder Platichthys flesus L. exposed to sublethal levels of cadmium. Aquatic Toxicol. 1:19-35.

TABLE 4.1 Metals levels in sediment and water samples from Polluted and Control tanks.

	Sediment (ug/g dry weight)		Water (ug/kg H_2O)	
	Polluted	Control	Polluted	Control
Arsenic	5.86-7.70	1.10-2.19		
Cadmium	0.58-1.23	<0.25	0.085	0.076-0.120
Copper	108-305	8.2-9.3	5.049	3.920-4.400
Lead	70-150	<2.5	0.668	1.712-1.912
Zinc	135-240	22.3-29.4	1.732	2.538-11.460

5. ANALYSIS OF BEAUFORT SEA SURFICIAL MARINE SEDIMENTS

D.J. Thomas

Contractor: Arctic Laboratories Limited
Prepared for: W. Fenton, E.P.S. Yellowknife

The Beaufort Sea Shelf adjacent to the Mackenzie River Delta and Tuktoyaktuk Peninsula has been the site of offshore hydrocarbon exploration during the past decade. A marine base at Tuktoyaktuk Harbour has been used to support the offshore effort during this period. More recently, a marine base at McKinley Bay has been created by dredging operations; it is used as a harbour for over-wintering the marine fleet, as a supply base and as an industrial maintenance centre. Ship traffic joins Tuktoyaktuk Harbour to McKinley Bay and the offshore exploration zone.

The expectation is that the use of the marine bases and shipping corridors along the Tuktoyaktuk Peninsula will increase in the future as development of Beaufort Sea hydrocarbon resources continues. It was recognized that a coherent data set of sediment geochemistry and benthic invertebrate biology was required to assess any potential effects resulting from the industrial activity.

As a result, a coastal sediment reconnaissance survey, comprising beach and marine sediment sampling, was conducted by the Environmental Protection Service (Yellowknife) along the Tuktoyaktuk Peninsula during the summer of 1982. The objectives of this survey were:

1) to initiate a multi-year sampling program to monitor the occurrence of heavy metals and hydrocarbons in the sediments at exploration shorebases and support developments at McKinley Bay, Tuktoyaktuk Harbour and Tuft Point, relative to that at Hutchison Bay (taken as a reference location), so as to produce information that can be used to evaluate marine environmental quality at these sites and to evaluate the effectiveness of regulatory controls;

2) to measure baseline petroleum hydrocarbon concentrations in sediments along the shoreline of Tuktoyaktuk Peninsula from Tuktoyaktuk to McKinley Bay;

3) to examine the spatial distribution of sediment grain size and hexane extractable compounds within McKinley Bay; and

4) to investigate the relationship between sediment contaminant concentrations and sediment properties and hydrodynamic history (such as grain size, water depth, and influence of the Mackenzie River plume) in the nearshore zone of the Beaufort Sea along the Tuktoyaktuk Peninsula.

Sediment samples were collected at 110 stations (43 beach, 67 marine); samples of benthic invertebrates were collected at 53 stations (all marine) during the period mid-July to mid-August and again at 42 of the 53 stations in late August-early September. The sampling locations are shown in Figures 5.1 to 5.5.

The samples were analysed by Arctic Laboratories Limited for the following geochemical parameters:

- sediment grain size;
- wet weight, ash weight, dry weight;
- total organic carbon;
- hexane extractable compounds;
- total chromium;
- total iron;
- total nickel;
- total copper;
- total zinc;
- total cadmium;
- total mercury;
- total lead; and
- hydrocarbons:
  a) aliphatic - total and quantification of n-alkanes from nC_{10} to nC_{33}, phytane and pristane, and

  b) polynuclear aromatics - total and quantification of naphthalene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzofluoranthenes, benzo(e)pyrene, benzo(a)pyrene and perylene.

Taxonomic identification and enumeration of the benthic biota to class/order was conducted by E.P.S. Yellowknife.

At the present time all the analytical results have been published in data report format (Thomas et al, 1983). It is too early to speculate on the meaning of the results. Detailed analysis and interpretation of the data, however, are on-goining. A second year (1983) of sampling has been completed and will add to the data base. Information on the status of the interpretive phase of the study or any other aspects of the programme may be obtained by contacting:

District Director
Environmental Protection Service
P.O. Box 370
9th Floor, Bellanca Building
Yellowknife, N.W.T. X1A 2N3
PH: (403) 873-3456

REFERENCES

Thomas, D.J., P.R. Wainwright, B.D. Arner and W.H.Coedy. 1983. Beaufort Sea coastal sediment reconnaissance survey: a data report on 1982 geochemical and biological sampling. Prepared for E.P.S. Yellowknife by Arctic Laboratories Limited. 459 pp.

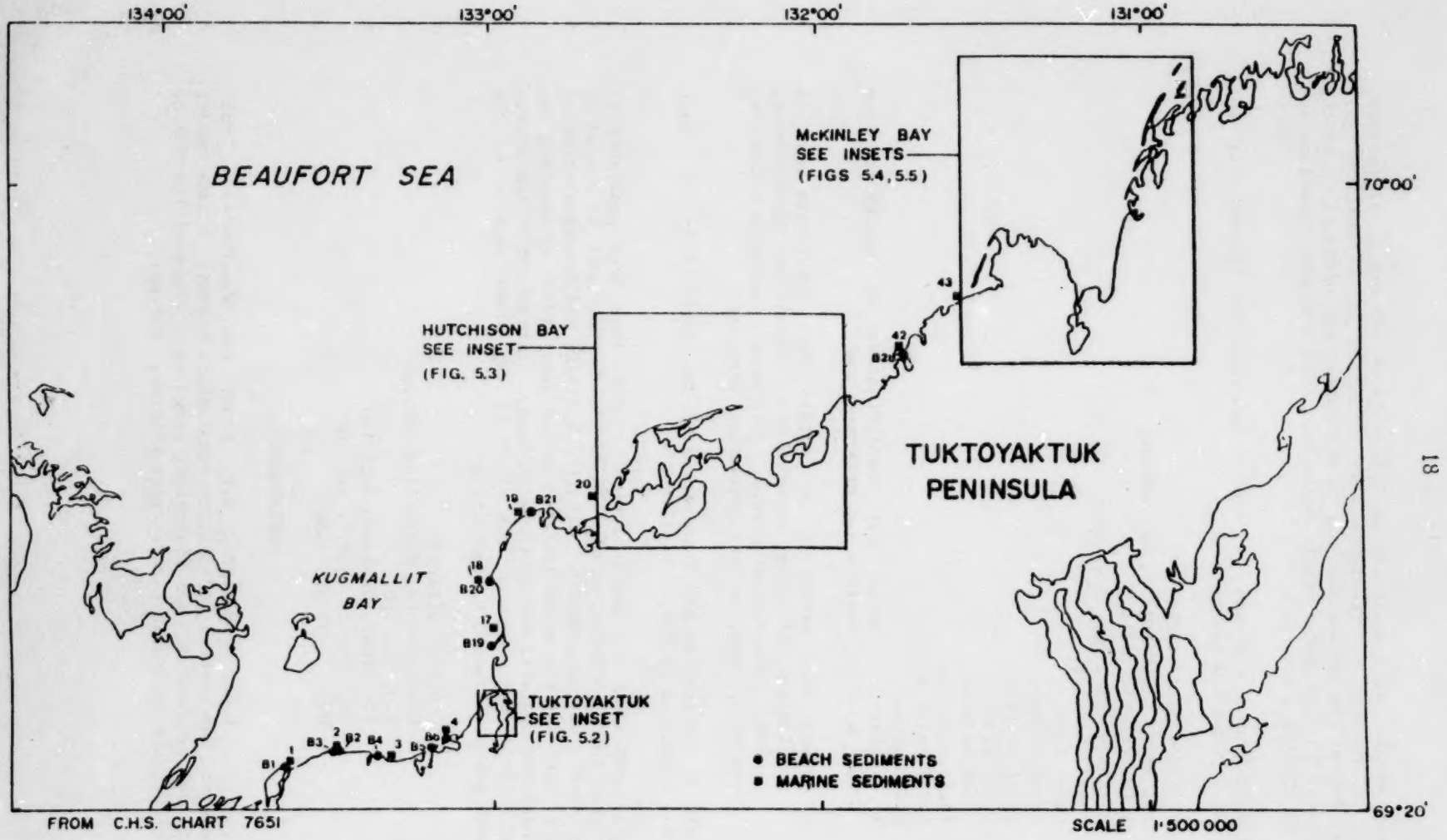

FIGURE 5.1 Tuktoyaktuk Peninsula from Kugmallit Bay to McKinley Bay showing station locations at which marine and beach sediment samples were collected during the 1982 Coastal Sediment Reconnaissance Survey. Only those sampling locations which occur outside the area of Figures 5.2 - 5.5 are shown here.

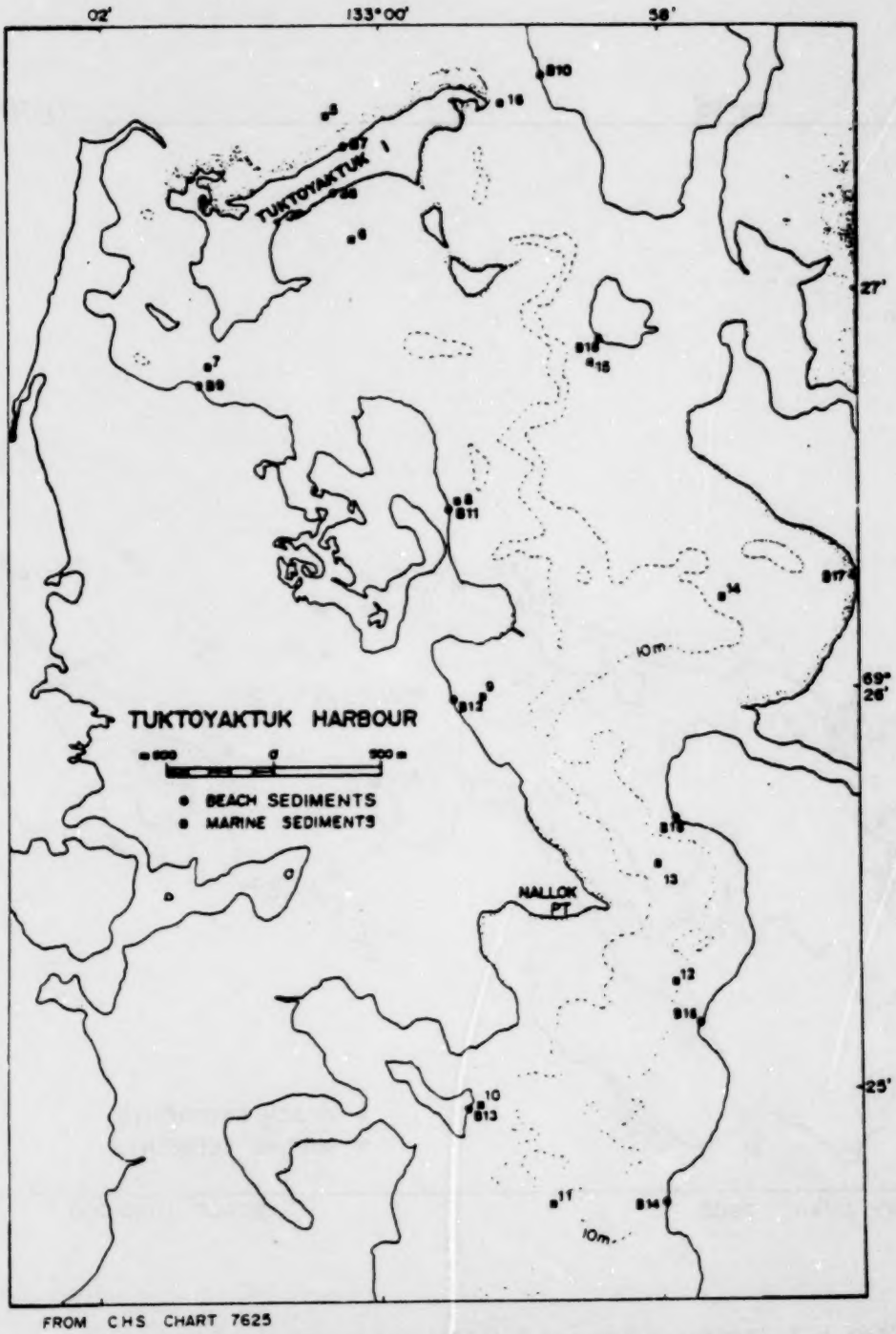

FIGURE 5.2 Tuktoyaktuk Harbour showing station locations at which marine and beach sediment samples were collected during the 1982 Coastal Sediment Reconnaissance Survey.

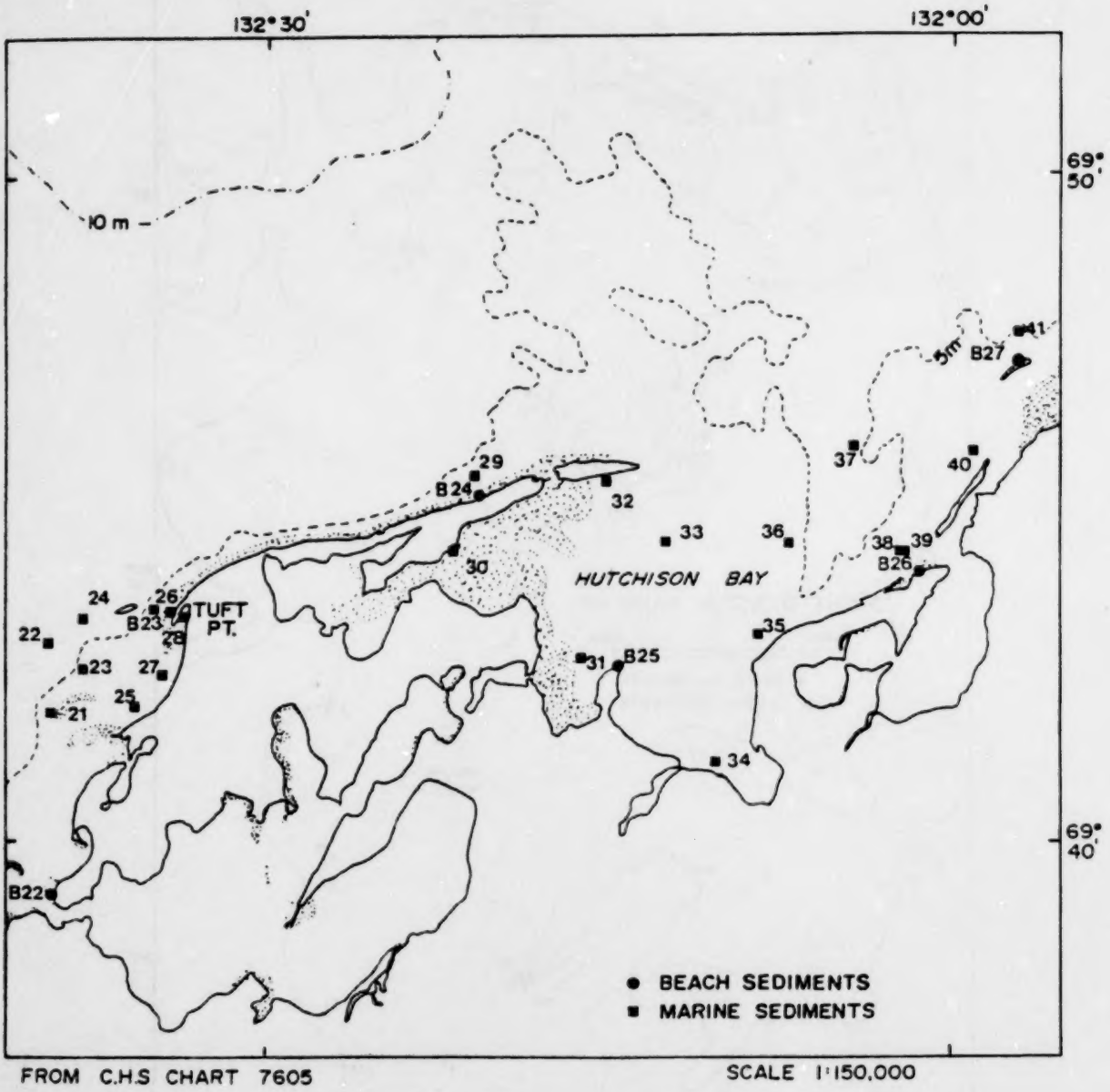

FIGURE 5.3 Hutchison Bay and Tuft Point area of the Tuktoyaktuk Peninsula showing station locations at which marine and beach sediment samples were collected during the 1982 Coastal Sediment Reconnaissance Survey.

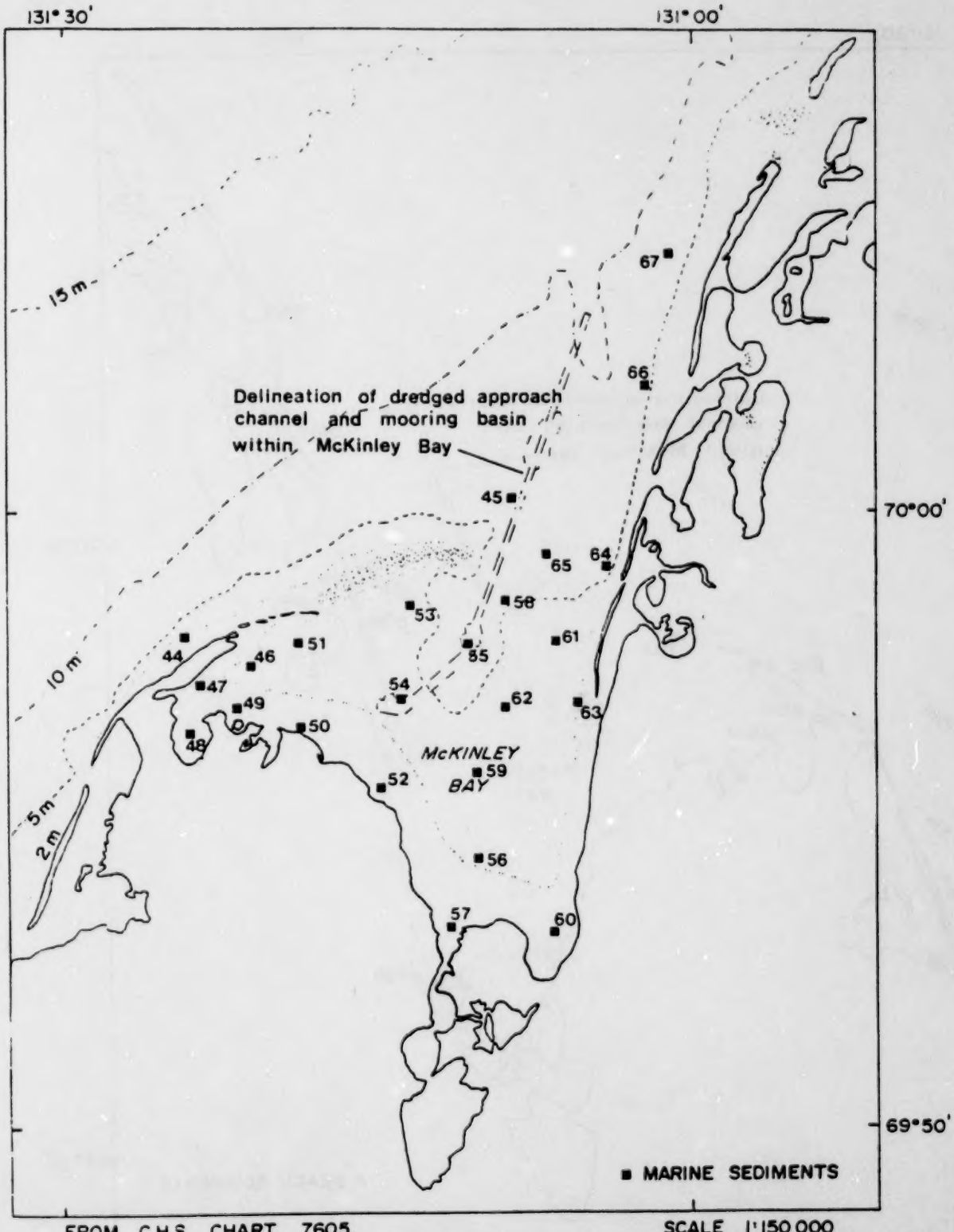

FIGURE 5.4 McKinley Bay and adjacent waters showing station locations at which marine sediment samples were collected during the 1982 Coastal Sediment Reconnaissance Survey.

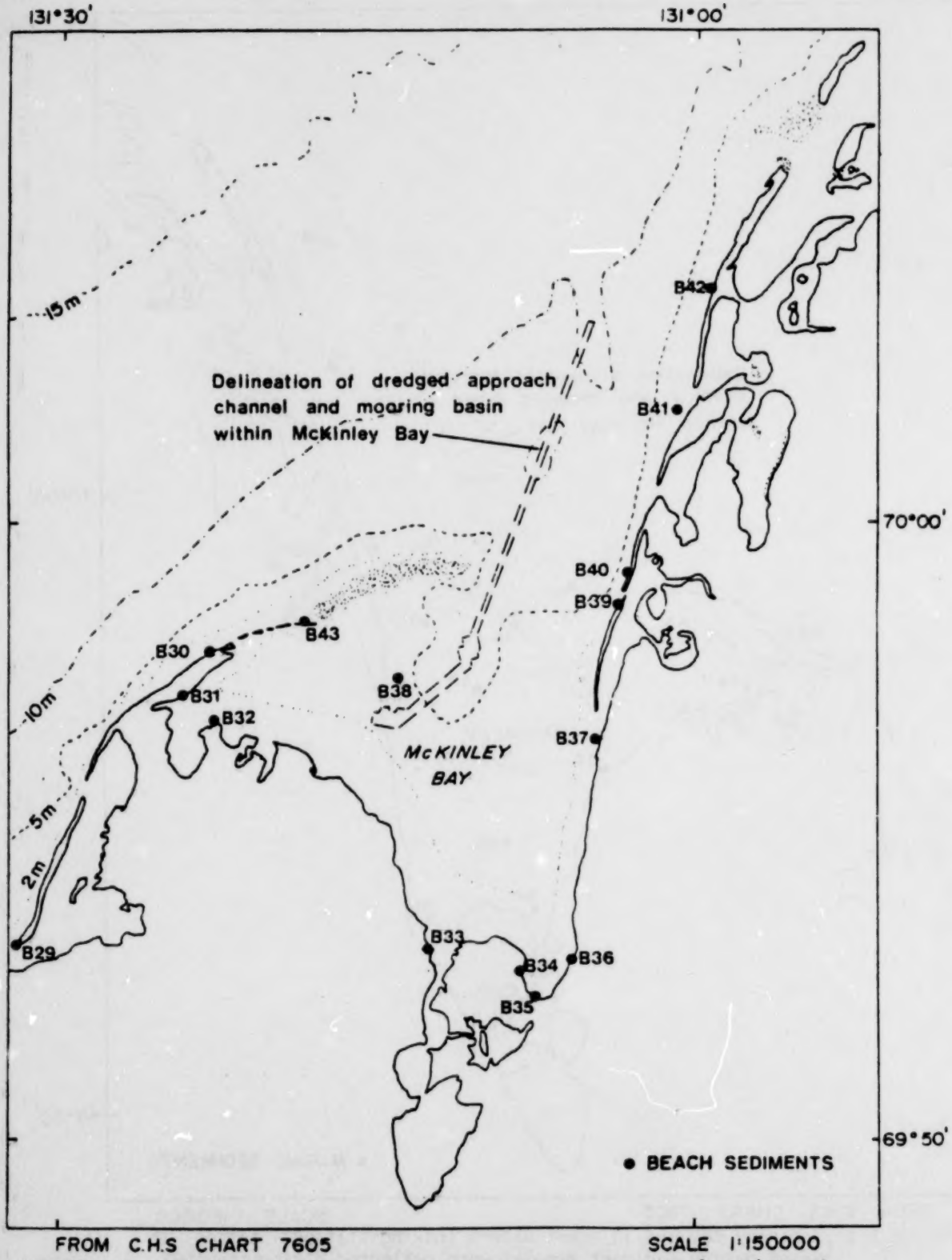

FIGURE 5.5 McKinley Bay and adjacent waters showing station locations at which beach sediment samples were collected during the 1982 Coastal Sediment Reconnaissance Survey.

6. RELATIONSHIPS BETWEEN TOXIC CHEMICALS AND SERIOUS DISEASE IN FISH FROM POLLUTED ENVIRONMENTS: THE EXAMPLE OF PUGET SOUND

D.C. Malins

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Environmental Conservation Division
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Multidisciplinary studies of relationships between pollutants and diseases in bottom-dwelling fish in Puget Sound have revealed high concentrations of a large number of anthropogenic chemicals in sediments. For example, over 900 organic chemicals (including certain aromatic hydrocarbons [AHs] and various chlorinated compounds) were detected in sediments from Commencement Bay (Tacoma) and evidence was found for additional types of organic xenobiotics and metals. High levels of some of these chemicals (which are known to accumulate in bottom-dwelling fish) in urban bays have been linked to serious diseases, such as liver carcinomas (neoplasia), in English sole (Parophrys vetulus) and other demersal species (Malins et al., 1982).

Urban embayments studied in Puget Sound were Elliott Bay (Seattle), Commencement Bay, Budd Inlet (Olympia), Sinclair Inlet (Bremerton) and Port Gardner (Everett). Nonurban embayments studied were Case Inlet, Port Madison and Port Susan. Discovery Bay, close to the northern entrance to Puget Sound, was also studied. A variety of statistical and mathematical methods were used to evaluate possible relationships between the data on chemistry and fish diseases.

Positive correlations were found between the frequencies of liver neoplasms and other liver lesions in English sole and Pacific staghorn sculpin (Leptocottus armatus) and concentrations of AHs and/or metals in sediment; such correlations obtained between AHs and liver neoplasia in English sole are consistent with results obtained from metabolism studies with fish exposed to toxic chemicals in our laboratories. These laboratory studies showed that a higher proportion of benzo[a]pyrene [BaP] 7,8-diol (the penultimate carcinogen of BaP) and a greater degree of co·alent binding occur in sole liver compared to rat liver (Gmur and Varanasi, 1982; Varanasi et al., 1981). Moreover, recent findings from another laboratory suggest that DNA excision-repair is distinctly low in fish compared to mammals (Regan et al., 1983).

In one study, using electron paramagnetic resonance spectroscopy, we showe' that hepatic lesions in English sole from polluted urban bays contained free radical derivatives of polynuclear aromatic compounds (Malins et al., 1983a). The free radical concentrations were higher ($p < 0.05$) in microsomes from livers with lesions compared to the concentrations in microsomes from livers without lesions. We recently established that the free radicals identified in livers with lesions

consisted of carbazole-N-oxyls which are believed to be derived from carbazoles (nitrogen heterocyclics) present in Puget Sound sediments (Malins et al, 1983b). A number of carbazoles are potent hepatocarcinogens.

Positive correlations which were obtained between sediment-associated metals and liver neoplasms in English sole are not easily reconciled. A direct carcinogenic effect is possible; however, the possibility also exists for indirect effects, such as disease resulting from metal-induced changes in levels of "reductants" - for example, ascorbic acid and reduced glutathione - which provide a defense against the actions of toxic chemicals.

The field and laboratory studies have provided important initial insights into cause-and-effect relationships between chemicals and diseases in fish. It is likely that similar investigations would reveal comparable serious pollution-related health problems in marine life in many other urban areas of the world.

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Malins, D.C., M.S. Myers, W.D. MacLeod and W.T. Roubal. 1983b. (Unpublished results). Presentation at the Second International Symposium on Responses of Marine Organisms to Pollutants, Woods Hole Oceanographic Institution, Woods Hole, MA, 1983.

Regan, J.D., R.D., Snyder, A.A. Francis and B.L. Olla. 1983. Excision repair of ultraviolet- and chemically-induced damage in the DNA of fibroblasts derived from two closely related species of marine fish. Aquatic Toxicol. 4:181.

Varanasi, U., J.E. Stein and T. Hom. 1981. Covalent binding of benzo[a]pyrene to DNA in fish liver. Biochem. Biophys. Res. Comm. 103:780.

(Recognition is expressed to the following contributors to this work: Bruce B. McCain, Donald W. Brown, Sin-Lam Chan, Mark S. Myers, John T. Landahl, Edmundo Casillas, Patty G. Prohaska, Andrew J. Friedman, Linda D. Rhodes, Douglas G. Burrows, William D. Gronland, William T. Roubal and Harold O. Hodgins.)

7. REGULATING CERTAIN LIMITS WITH UNCERTAIN NUMBERS

R.W. Macdonald

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Institute of Ocean Sciences
Sidney, B.C.

Variance in analytical data from environmental samples can arise from at least two sources:

$$s^2_{Total} = s^2_{Environ} + s^2_{Analytical}$$

With refinement, each of these sources of variance could be broken into further component parts. This report will not examine the environmental contribution (patchiness and sampling problems) but rather will review the analytical state of affairs. Variance can arise from the analytical method and instrument, from different analysts in the same laboratory, or from different laboratories which use different methods. Furthermore, variance on one day may be smaller than that calculated for a longer time period. These are some of the difficulties in deciding whether or not a sediment proposed for dumping is in violation of the Ocean Dumping Control Act (O.D.C.A.).

The accuracy estimate is perhaps the most important property of data, especially in consideration of regulatory limits. Secondarily, if one wishes to relate data sets one to another, or examine trends over a period of time, some statement of accuracy is required. What is meant here by accuracy is not that the measured concentration is exactly equal to the true value (a desirable but impractical goal) but rather that limits of confidence, which are well founded statistically, can be expressed. Accuracy considered in this manner is comprised of two components: bias and random error.

Data in support of O.D.C.A. permit review process are accumulated under most unfavourable circumstances. Different methods are applied and analyses are carried out in different labs in various parts of the country. A brief review of the Pacific Region ocean dumping data files reveals that these problems are compounded by very incomplete reporting of methods and chain of custody/sampling, and, frequently, by the lack of a statement of accuracy.

If comparison is to be attempted, and "ocean dumping" decisions made within the variability of the real world, laboratories must determine their precision and accuracy for analyses of environmental samples. Use of r cognized control methods helps establish and maintain quality. The kinds of components which integrate to form an analytical determination include analytical methods, an instrument, a calibration process, a check on recovery or interference, and blanks. Most important is the analyst who performs this integration and ensures that the system works within its limits (detection limit ⟶ overload) and performs according

to realizable objectives including precision and bias (accuracy). The complete reporting of the above aspects helps in the interpretation and comparison of data so produced. Omission in reporting renders the data uninterpretable; omission in practice renders the data invalid. With time, as supporting information is discarded or lost, the difference between uninterpretable and invalid becomes academic.

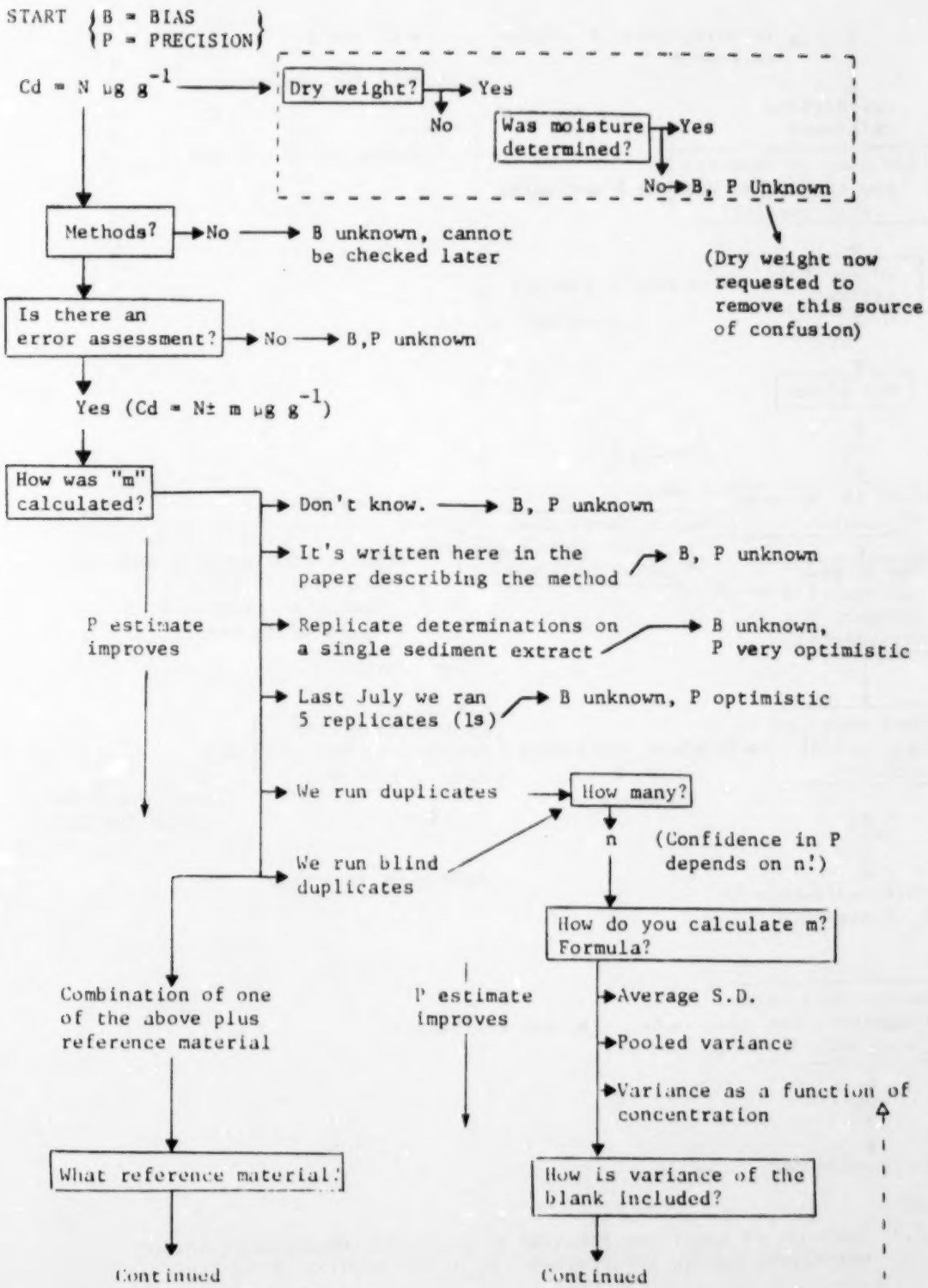
The problem of enforcing an exact legal limit with in-exact numbers can be seen by following a data "audit trail". In Figure 7.1 this is done by starting with the original information, a reported number or set of numbers. Experience in reviewing the data compiled from past permit applications indicates that, normally, data are provided very close to the top of the "audit trail" in Figure 7.1. The further down the trail one proceeds, the greater the confidence in knowing what the number means, and its likely error limits.

The series of questions and answers shown in Figure 7.1 is sketchy but illustrates the importance of complete reporting. Although statistical and procedural methods abound in the literature, these should not be used as a replacement for common sense. The lab manager has two tasks:

1) to establish control of the analytical system and to estimate in an unbiased fashion the confidence in the data, and

2) to report methods fully and explain how error estimates were made.

In the end there is no replacement for the integrity and skill of the analyst. However, feedback from well designed controls can help the analyst convince himself and others that the data are within the stated bounds. It then becomes possible to compare these data with regulatory limits or with data which have been collected in like manner.


START
B = BIAS
P = PRECISION
Cd = N µg g-1
Dry weight?
Yes
No
Was moisture determined?
Yes
No
B, P Unknown
(Dry weight now requested to remove this source of confusion)
Methods?
No
B unknown, cannot be checked later
Is there an error assessment?
No
B,P unknown
Yes (Cd = N± m µg g-1)
How was "m" calculated?
Don't know.
B, P unknown
It's written here in the paper describing the method
B, P unknown
P estimate improves
Replicate determinations on a single sediment extract
B unknown, P very optimistic
Last July we ran 5 replicates (1s)
B unknown, P optimistic
We run duplicates
How many?
n
(Confidence in P depends on n!)
We run blind duplicates
How do you calculate m? Formula?
Combination of one of the above plus reference material
P estimate improves
Average S.D.
Pooled variance
Variance as a function of concentration
What reference material?
How is variance of the blank included?
Continued
Continued

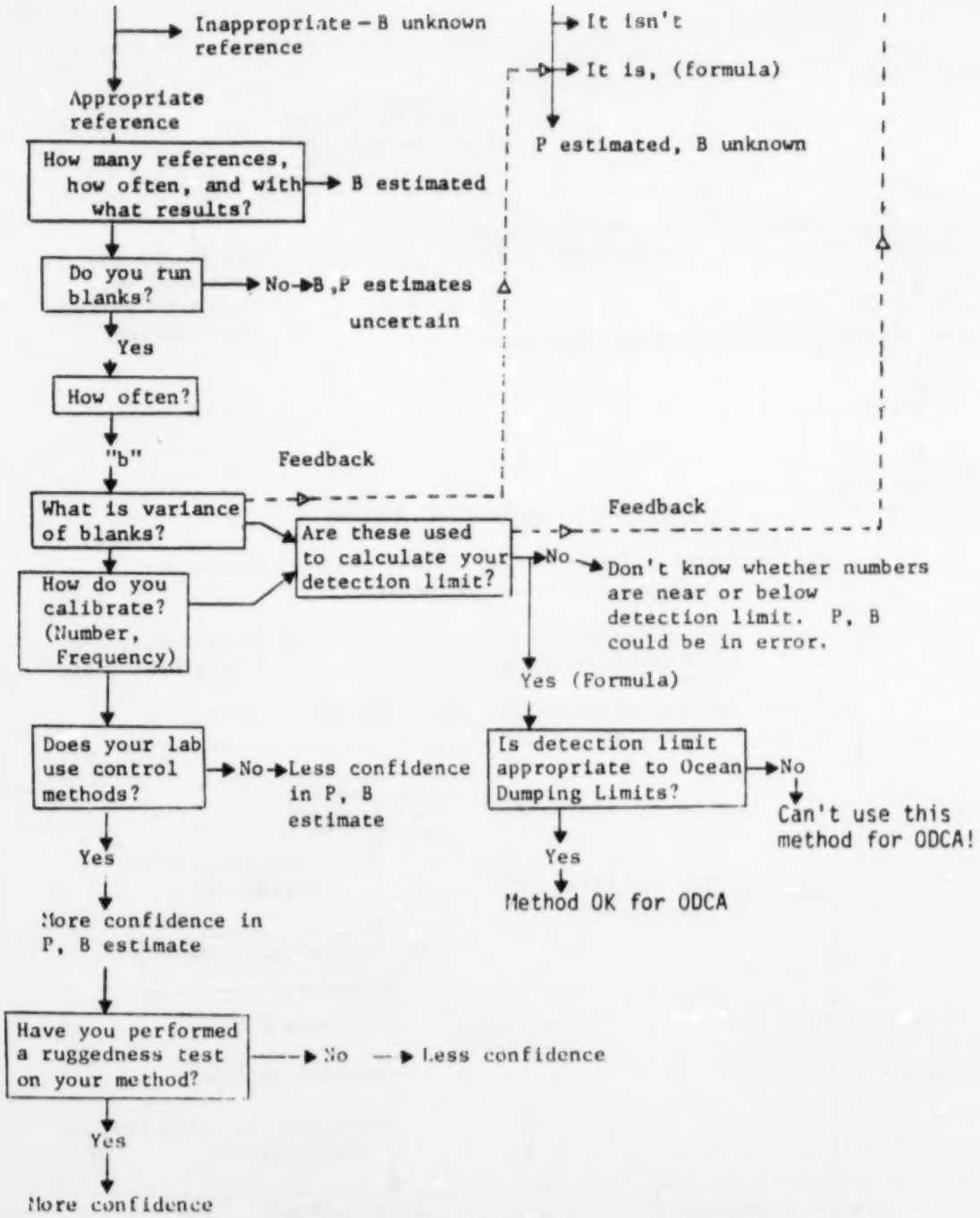

Inappropriate – B unknown reference
It isn't
It is, (formula)
P estimated, B unknown
Appropriate reference
How many references, how often, and with what results?
B estimated
Do you run blanks?
No → B, P estimates uncertain
Yes
How often?
"b"
Feedback
What is variance of blanks?
Are these used to calculate your detection limit?
Feedback
No
Don't know whether numbers are near or below detection limit. P, B could be in error.
How do you calibrate? (Number, Frequency)
Yes (Formula)
Does your lab use control methods?
No → Less confidence in P, B estimate
Is detection limit appropriate to Ocean Dumping Limits?
No
Can't use this method for ODCA!
Yes
Yes
Method OK for ODCA
More confidence in P, B estimate
Have you performed a ruggedness test on your method?
No → Less confidence
Yes
More confidence

FIGURE 7.1 Sequence of questions required to establish the bounds within which data can be interpreted. B refers to Bias, P to Precision.

8. DISCUSSION ON INTERLABORATORY COMPARISON AND QUALITY ASSURANCE PROTOCOL

In order to facilitate the decision-making process in terms of compliance with regulatory limits established under the Ocean Dumping Control Act, R.O.D.A.C. (Pacific) will be implementing a quality assurance protocol to commence in 1984.

The initial phase consists of a proposed round-robin laboratory performance check. All laboratories, both government and industrial, with capability and interest in performing sediment analyses will be invited to participate. Prior to the distribution of the samples, a protocol on 'the methods for assuring and evaluating quality in the analysis of marine sediments for metals' will be circulated along with a questionnaire which it is hoped will help laboratories perform better and report their results more completely. Some reference samples will be prepared and these, along with certified reference sediments (N.R.C., N.B.S.), will be disguised and distributed to the laboratories for analysis. Each laboratory will conduct the required analyses and will prepare a report on the metal contents in accordance with detailed instructions in the protocol. Along with the results of the analyses, the types of information to be submitted will include complete reporting of methods and chain of custody/sampling and statements concerning precision, accuracy and ruggedness. The information package for the laboratory will remain on file with R.O.D.A.C.

All applications for ocean dumping permits received by R.O.D.A.C. following the completion of the performance check will need to be accompanied by a certification that required analyses were conducted either in accordance with the methodology and quality control descriptions on file with R.O.D.A.C. for the laboratory which conducted the analyses, or in accordance with updated descriptions which must accompany the permit. Without such certification or accompanying information the ocean dumping permit will not be granted.

By acting in accordance with the above protocol, it is hoped that it will be possible to compare the analytical data with O.D.C.A. regulatory limits or with other data which have been collected in a similar manner.

APPENDIX I

LOCATIONS OF PARTICIPANTS 1983

I. Government

CANADA: Environment Canada:

E.P.S. - Environmental Protection Service
Kapilano 100, Park Royal South
WEST VANCOUVER, B.C. V7T 1A2

D.F.O. - Department of Fisheries and Oceans:

Habitat Management Division
Water Quality Unit
1090 West Pender Street
VANCOUVER, B.C. V6E 2P1

I.O.S. - Institute of Ocean Sciences
P.O. Box 6000
SIDNEY, B.C. V8L 4B2

W.V.L. - West Vancouver Laboratory
4160 Marine Drive
WEST VANCOUVER, B.C. V7V 1N6

Ministry of Environment, British Columbia:

Aquatic Toxicity Laboratory
1801 Welch Street
NORTH VANCOUVER, B.C. V7P 1B7

Marine Resources Branch
Parliament Buildings
VICTORIA, B.C. V8V 1X5

Planning and Assessment Branch
777 Broughton Street - 3rd Floor
VICTORIA, B.C. V8W 1E3

Waste Management Branch
810 Blanshard Street
VICTORIA, B.C. V8V 1X5

Ministry of Lands, Parks and Housing, British Columbia:
1019 Wharf Street
VICTORIA, B.C. V8W 2Y9

U.S.A.: N.O.A.A. - National Oceanographic and Atmospheric Administration:

Northwest and Alaska Fisheries Center
Environmental Conservation Division
2725 Montlake Boulevard East
SEATTLE, Wa. 98112

II. Industry

AMAX of Canada Limited
Box 12525 Oceanic Plaza
Suite 1600 - 1066 West Hastings
VANCOUVER, B.C. V6E 3X1

Analytical Service Laboratories Limited
1650 Pandora Street
VANCOUVER, B.C. V5L 1L6

Arctic Laboratories Limited
2045 Mills Road
SIDNEY, B.C. V8L 3S1

Associated Engineering Services Limited
1661 West 8th Avenue
VANCOUVER, B.C. V6J 1V1

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P.O. Box 11626
650 West Georgia
VANCOUVER, B.C. V6B 4N9

B.C. Research
3650 Wesbrook Crescent
VANCOUVER, B.C. V6S 2L2

Can Test Limited
1523 West 3rd Avenue
VANCOUVER, B.C. V6J 1J8

Chemex Laboratories Limited
212 Brooksbank Avenue
NORTH VANCOUVER, B.C. V7J 2C1

DEK Environmental Research Services
8565 Bedora Place
WEST VANCOUVER, B.C. V7W 2W4

Dobrocky SEATECH Limited
P.O. Box 6500
9865 West Saanich Road
SIDNEY, B.C. V8L 4M7

Edward Anderson Marine Sciences
10-2614 Bridge Street
VICTORIA, B.C. V3M 4S9

E.V.S. Consultants Limited
195 Pemberton Avenue
NORTH VANCOUVER, B.C. V7P 2R4
and
2035 Mills Road
SIDNEY, B.C. V8L 3S1

L.G.L. Limited
333 - 2453 Beacon Avenue
SIDNEY, B.C. V8L 1X7

MacMillan Bloedel Limited
1075 Georgia Street
VANCOUVER, B.C. V6E 3R9

McLeay and Associates Limited
8320 Rosehill Drive
RICHMOND, B.C. V7A 2J7

Plumper Ocean Projects Limited
319 Stewart Avenue
VICTORIA, B.C. V4R 1R6

Quanta Trace Laboratories Incorporated
401 - 3700 Gilmore Way
BURNABY, B.C. V5G 4M1

Rescan Environmental Services Limited
Suite 1105 - 1177 West Hastings Street
VANCOUVER, B.C. V6E 2K3

Sea-I Research
Box 2282
Suite 106 - 9865 West Saanich Road
SIDNEY, B.C. V8L 3S8

Seakem Oceanography Limited
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Willis Cunliffe Tait/DelCan
827 Fort Street
VICTORIA, B.C. V8W 1H6

III. University

Department of Biology
University of Victoria
P.O. Box 1700
VICTORIA, B.C. V8W 2Y2

APPENDIX II

OCEAN DUMPING WORKSHOP ATTENDANCE LIST

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M. Yunker, Dobrocky SEATECH Ltd., Sidney, B.C. (604-656-0111)

APPENDIX III

1982-1983 CONTRACTS
PACIFIC REGION

1.	A histological assessment of sublethal effects of ocean dumped material on benthic organisms in Alberni Inlet, B.C. (Amendment to 1981-82 contract.)	$10,000
	Scientific Authority: W. Cretney, D.F.O./I.O.S. Contractor: Seakem Oceanography Limited D.S.S. File No.: 08SB. FP 833-1-0769	
2.	Bioaccumulation and sublethal toxicity of cadmium, lead and zinc from sediments by polychaete worms and flatfish.	$20,000
	Scientific Authority: J. Thompson, D.F.O./I.O.S. Contractor: Dobrocky SEATECH Limited D.S.S. File No.: 08SB. FP 941-1-3446	
3.	Development and evaluation of a bioassay protocol for predicting the bioaccumulation potential of sediment-associated contaminants.	$15,000
	Scientific Authority: H. Nelson, E.P.S. Contractor: E.V.S. Consultants Limited D.S.S. File No.: 03SB. KE-2-0449	
4.	Release rates of metals to seawater from contaminated sediments. (Subcontract: Analysis of extracts of seawater for ultratrace metals by mass spectrometry.)	$16,000
	Scientific Authority: C. Wong, D.F.O./I.O.S. Subcontractor: Seakem Oceanography Limited Subcontract D.S.S. File No.: 08SB. FP 941-2-0965	($10,174)
5.	Analysis of surficial marine sediments.	$13,000
	Scientific Authority: W. Fenton, E.P.S. Contractor: Arctic Laboratories D.S.S. File No.: 08SB. FP 941-2-0909	
6.	Organization and summary of ocean dumping workshops.	$ 4,741
	Scientific Authority: A. Cornford, D.F.O./I.O.S. Contractor: Dobrocky SEATECH Limited D.S.S. File No.: 06SB. FP 941-2-2108	

APPENDIX IV

1983-1984 CONTRACTS
PACIFIC REGION

1. Use of statistical analyses of large sediment data sets to provide specifications for ocean dumping quality control. $14,000

   Scientific Authority: R.W. Macdonald, D.F.O./I.O.S.
   Contractor: Dobrocky SEATECH Limited
   D.S.S. File No. 06SB. FP 941-3-1200

2. Effect of wood wastes on the recruitment potential of marine benthic communities. $15,000

   Scientific Authority: M. Waldichuk, D.F.O./W.V.L.
   Contractor: E.V.S. Consultants Limited
   D.S.S. File No.: 06SB. FP 941-3-1318

3. Development of fish habitat on dredged material at Campbell River Estuary. $15,000

   Scientific Authority: C.D. Levings, D.F.O./W.V.L.
   Contractor: Edward Anderson Marine Sciences
   D.S.S. File No.: 06SB. FP 941-3-0179

4. A shipboard method for evaluating the toxicity of dredge-spoils and sediments using micro-organisms. $10,000

   Scientific Authority: N. Antia, D.F.O./W.V.L.
   Contractor: Atlantic Oceanics Company Limited
   Subcontractor: Seakem Oceanography Limited
   D.S.S. File No.: 03SB.KE603-3-0806

5. Organization of west coast ocean dumping workshop and preparation of workshop proceedings for publication. $ 5,000

   Scientific Authority: A. Cornford, D.F.O./I.O.S.
   Contractor: Dobrocky SEATECH Limited
   D.S.S. File No.: 06SB. FP 941-3-2244